Measurements of magnetic fluctuations using a multiple Hall probe at TEXTOR

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1. Introduction

To investigate the magnetic field together with fluctuations induced by perturbation fields, a new multiple Hall probe diagnostic has been developed at TEXTOR ($R/a = 1.75/0.46\ m$, $B_T = 1.3 - 2.9\ T$, $I_p = 200 - 800\ kA$, $n_e < 8.10^{19}\ m^{-3}$, $T_{ei} \approx 1keV$). Fluctuating fields will be created by the forthcoming dynamic ergodic divertor (DED), where the installation has started on TEXTOR. Depending on the chosen degree of ergodization, the magnetic perturbation fields will be in the order of several mT. Measured levels of radial magnetic field fluctuations in discharges without perturbation coils are typically very small ($\tilde{B}_r/B_T \approx 10^{-4} - 10^{-5}$). However, during disruptions the magnetic perturbation on TEXTOR can be up to several mT. Using windowed Fourier analysis on measured signals a reasonable time and also frequency resolution can be obtained. As a result, it is possible to infer the time evolution of rotating islands caused by magnetic instabilities within the plasma.

2. Experimental arrangement

The major advantage of Hall probes as compared to conventional magnetic coils is their smaller size and the direct relation of the measured signal to the magnetic field. Because Hall probes are made of semiconductors, they need cooling and they are sensitive to neutrons, i.e. they need a more sophisticated experimental setup.

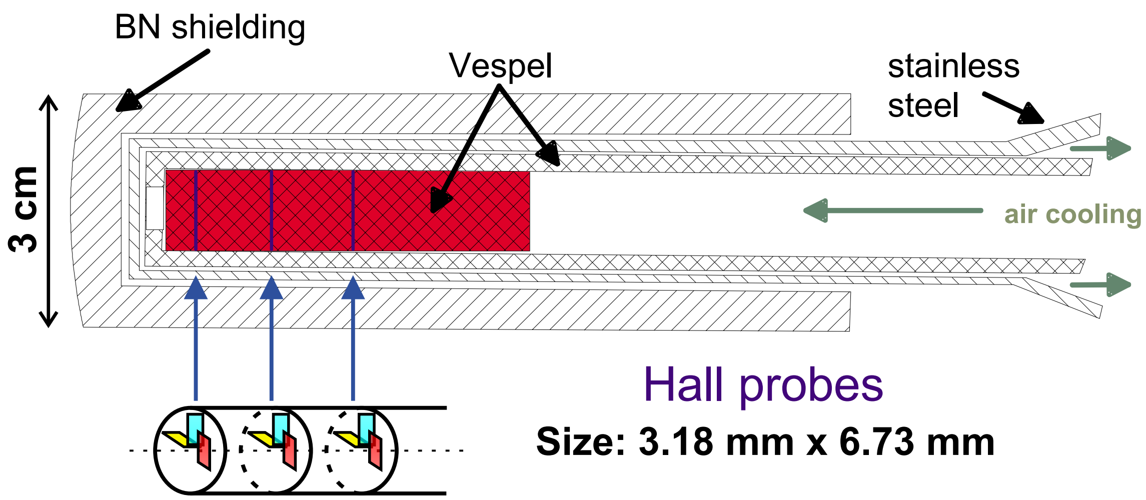

Fig. 1: Hall probes array.

On TEXTOR we have used all together 9 air cooled Hall probes, arranged on 3 different surfaces spaced by 1 cm, measuring the 3 components of the magnetic field. The probes have the dimensions 3.18 x 6.73 x 0.5 mm^3. As a result, it is possible to measure B_r, B_θ and B_T simultaneously at 3 radial locations in a single shot. Each Hall probe is fixed in an insulating (vespel) support, shielded by a cylinder (d=3.5 cm, l=10 cm) and covered by boron nitride. The probe head is mounted on a moveable holder. It could be inserted into the scrape-off-layer (SOL) about 4 cm outside the last closed flux surface.

Each Hall probe has been calibrated absolutely in the frequency range 1.4–100 kHz using an RLC oscillating circuit, which produces a damped sinusoidally oscillating magnetic field with an amplitude in the range of those to be found on TEXTOR. Modifying the circuit parameters, the frequency could be varied. The sensitivity of the diagnostics is 1 V/mT and the same for all Hall probes. The diagnostics allows measurements of magnetic fluctuations < 0.1 mT within the frequency band 100 Hz up to 80 kHz.

3. Experimental results

The measurements and the data evaluation given in this section have been obtained for a variety of experimental regimes on TEXTOR and they are primarily intended to explore the capability of Hall probes for measurements in tokamak plasmas. More detailed studies are envisaged, when the DED coils are in operation on TEXTOR.

3.1 Study of disruptions. Several experimental campaigns on TEXTOR have been dedicated to study disruptions. During these shots a pronounced MHD activity does show up, which makes these discharges a perfect testbed for any magnetic diagnostics.

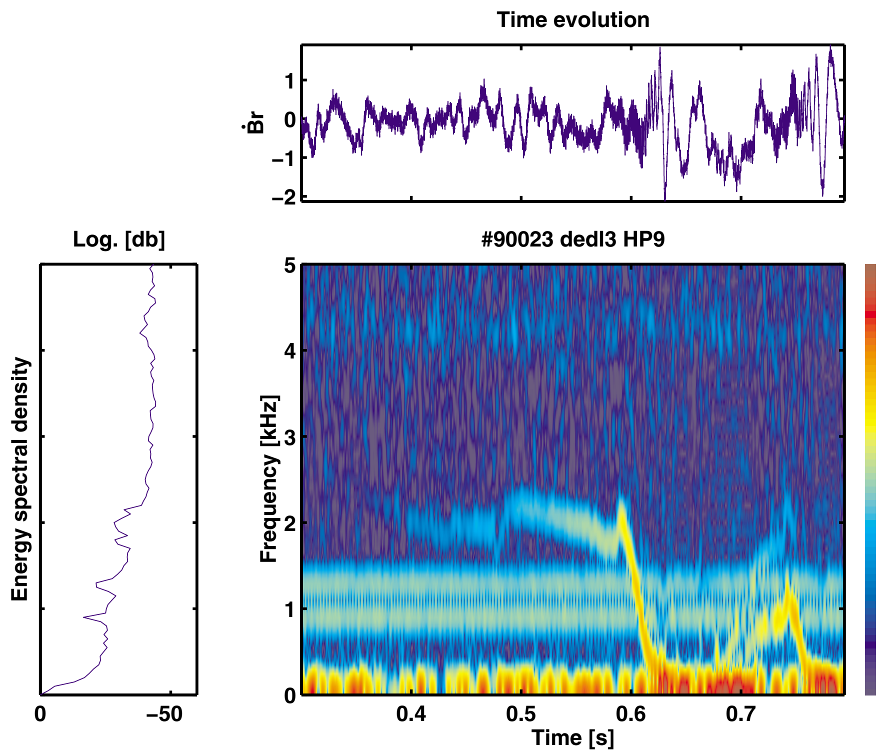

Fig. 2: Time-frequency plot of $\dot{B}_r$ signal during disruption.

Figure 2 shows in it's upper panel a time trace of the Hall probe signal measuring the radial field component during the last 0.5 s of discharge #90023 which got terminated due to a disruption. The onset of a MHD activity is apparent at 0.63 s and a major disruption follows at 0.79 s. The left panel of the fig. 2 shows the spectral density of the signal mentioned above. The 2D plot in the middle is a time-frequency (TF) representation of the measured signal. Two features dominate the plot. The magnetic feedback positioning system of TEXTOR causes over the entire discharge a constant perturbation at the fixed frequencies 0.9 and 1.3 kHz. An increase of the magnetic signal in the frequency band around 2 kHz is observed from 0.4 s and it is caused by a growth of a MHD instability. In the time interval 0.6–0.63 s the instability grows rapidly which is accompanied by a decrease of the frequency below 300 Hz. After this first disruptive event the plasma recovers, however, the next MHD instability that appears at 0.7 s already leads to a major disruption.

3.2 Sawtooth precursors. The sawtooth crash in tokamaks is preceded by a m=1 mode activity called the precursors. The recording of several sawtooth precursors is displayed in fig. 3. The central TF plot is supplemented by a time evolution of the measured signal (upper plot) and the spectral density (left plot).

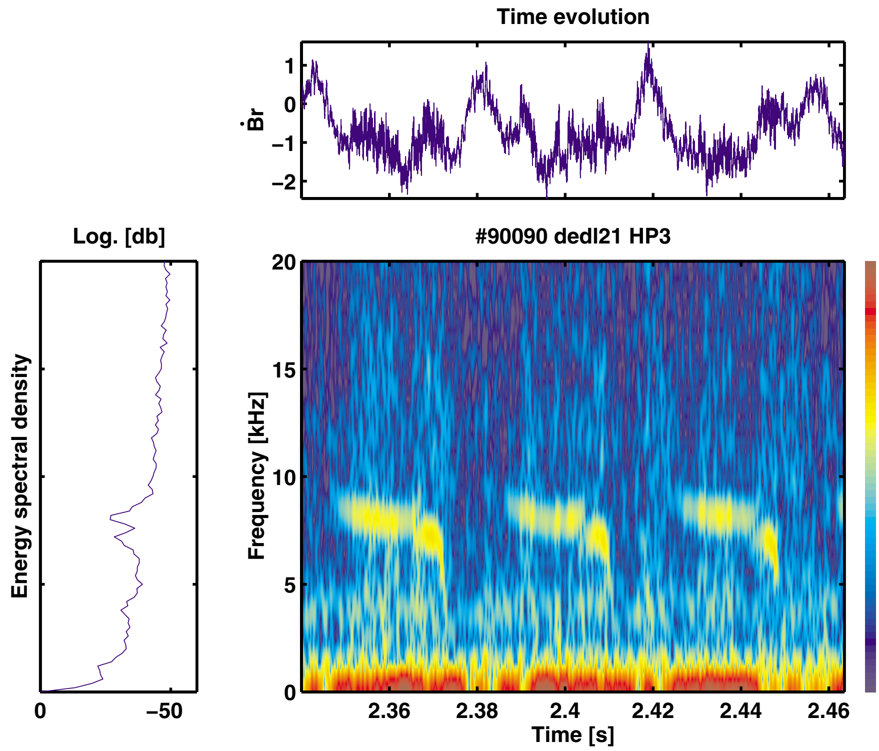

Fig. 3: Record of sawteeth precursors.

The duration of a single sawtooth precursor can be 20 ms. However, it was found that the shape of the TF plot in the first 15 ms of each precursor regularly differs from that in the last 5 ms. This indicates, that two different phenomena are at work and not a single one. Sawtoothing is not jet understood in detail.

3.3 Measurements during RI mode. The RI mode on TEXTOR is an experimental regime where improved confinement is obtained by edge cooling using noble gases, e.g. neon. This edge cooling reduces turbulence preferentially in the high frequency band [1]. We can confirm this as it becomes evident from fig. 4. The top panel shows the time evolution of $\dot{B}_r$ signal just before while the middle one during RI mode. The bottom panel compares frequency spectra corresponding to these two time intervals. Decrease of magnetic turbulence in RI mode over the whole spectrum is evident. However, we found this result only, when β_N had been feed back stabilized, whereas without stabilization the spectra looked the same or even an increase of the turbulence was observed after neon injection.

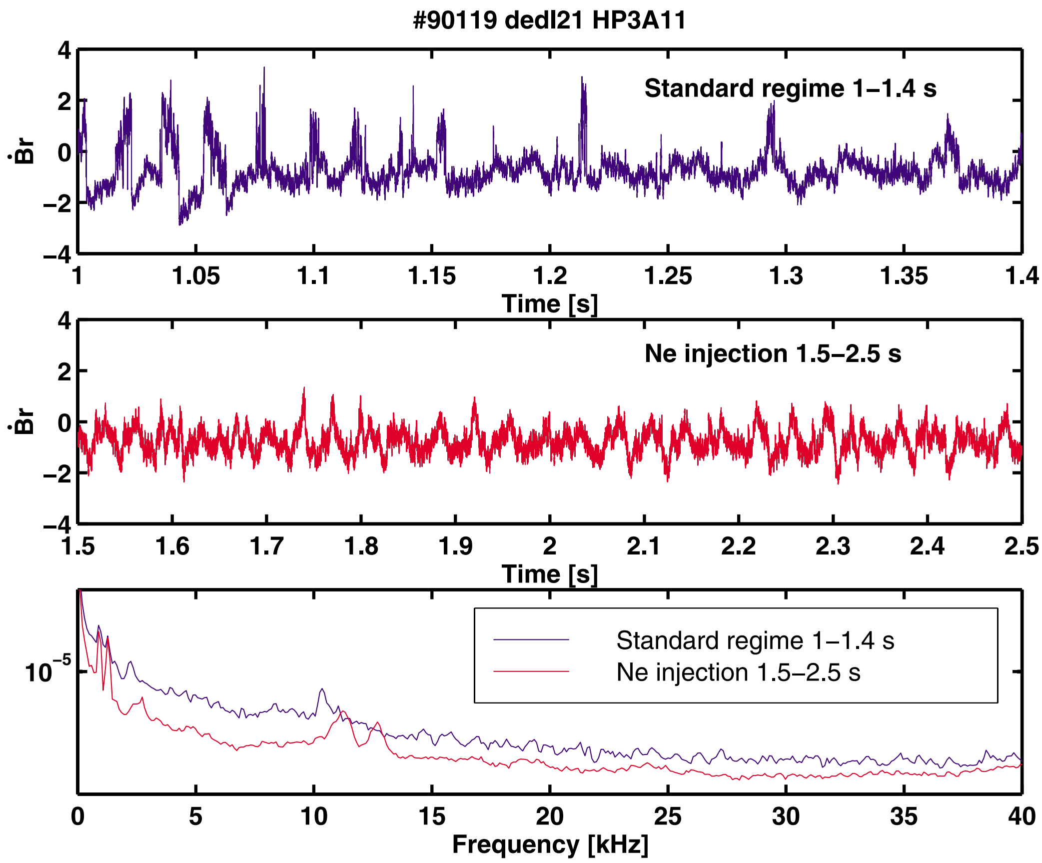

Fig. 4: Suppression of magnetic turbulence over the whole spectrum in RI mode with energy feedback.

Another feature of the magnetic turbulence during the RI mode is, that the spectra show changes in the frequency band from 5 to 10 kHz, depending on the energy confinement time, whereby the frequency increases with confinement time. More measurements and comparison of different profiles will be necessary in order to understand this finding.

4. Conclusions

A new diagnostic, array of 9 Hall probes was successfully tested on TEXTOR tokamak. Large magnetic islands are detected and the time evolution of their rotation frequency is followed in time. Sawtooth precursors together with their fine structure are clearly observed. Overall decrease of magnetic turbulence in RI mode discharges with energy feedback stabilization is observed. Some features of the magnetic fluctuations seen in the frequency spectra measured during RI mode are found to be directly related to plasma confinement. Better understanding of the above mentioned phenomena requires additional information on profiles, and comparison with other diagnostics.

References

[1] J.C. DeBoo et al.: 42nd Annual Meeting of the Division of Plasma Physics, Quebec City, Canada, Oct. 23-27, 2000.